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Final Report for Two XTE A01 Projects:: A Multi-frequency Study of Circinus X-1 and A Search for Microsecond Variability from Bright Galactic X-ray Sources

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1 Overview

Dr. Jernigan is a Co-I on each of these projects and is supporting the work of Drs. Bradt and Morgan both of the Center for Space Research, MIT. The first project (A01 10122) is titled A Multi-frequency Study of Circinus X-1 with PI Prof. Hale Bradt of MIT. The second project (A01 10063) is titled A Search for Microsecond Variability from Bright Galactic with PI Dr. Edward Morgan of MIT.

Dr. Jernigan work is focused on a single common portion of each of these projects. The theory for a new method for the determination of the "fastest" variability present in an X-ray source has been developed. A prototype code is functional which uses this new method which is a variation of a Kolmogorov-Smirnov test. The current phase involves testing of the newly developed code on real example sources (CYG X1). Unfortunately there are no calibration sources for testing the code which therefore required the development of a X-ray source simulation code. The goal is to evaluate the sensitivity of the code for the detection of a range of different type of variability (bursts, pulsations etc).

The new method utilizes a Kolmogorov-Smirnov (KS) test for detecting the cutoff at the fastest time scales due to finite size of the emission region. This method which is independent of the particular model for the time variation in the source. The concept is to measure the "size of the emitting region" of either a black hole (BH) or neutron star (NS) without explaining the details of the X-ray emission. This is similar to using X-ray pulsations to measure the orbit and mass of a neutron star without attempting to understand the reasons that the pulsation exists.

Following the point of view of Press and Schechter (1974 Ap.J. 193,437-442), one needs a method which measures fast time variations that are not "spurious" but instead are "real" signatures in the X-ray output of the source. The problem is clearly caused by the finite number of photons detected in a real system. Press and Schechter do not offer a practical analysis method that addresses their view but rather just point out the "danger" of incorrect interpretation. The new analysis method is a useful way to analyze timing data that avoids the problems that they site.

2 Summary of Method

The data is viewed in the form of a list of arrival times of X-rays with the assumption that the time tags are much better than the average time between X-rays. This is true for bright source detected by XTE since XTE can time tag each X-ray to 1 microsecond while the mean time between X-rays is hundreds of microseconds. X-rays are counted in 1 microsecond bins for some finite time. We parameterize a smoothing function which convolves the time series removing all structure on time scales faster than the smoothing scale. One then performs a two sample KS test that compares the smoothed and raw data as a function of the smoothing time scale. There are two possible reasons the KS value falls below statistical threshold. If the number of X-rays detected is too small (weak source, small detector, or insufficient observation time) then one can only set an upper limit on the fastest time scale in the source. If the number of X-rays is high enough, one hopes that

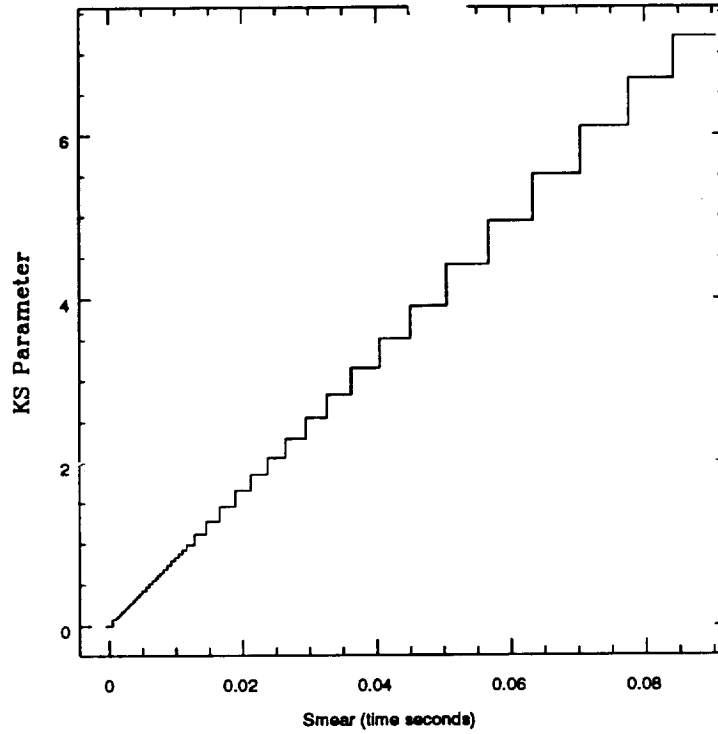


Figure 1: Simulation and analysis of Cygnus X-1

the KS parameter will drop quickly (a knee in the KS curve) to show a real cutoff in the source. Seeing the knee does depend on the level of variability at fast time scales present in the source.

The curve in Fig. 1 is an example of such an analysis of simulated data from Cyg X-1. Note that the KS parameter becomes greater than unity for a smoothing time greater than about 0.01 second. Therefore the test confirms measurable variability at least as fast as 0.01 seconds independent of the nature of the variability.

3 Status of Project

The KS method code is functional and will be applied to the analysis of Cir X-1 (project 10122) or GX 5-1 (project 10063) soon.